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RELIABILITY OF A NEW INSTRUMENT AND TECHNIQUES

FOR MEASURING JOINT RANGE OF MOTION

IN THE LOWER EXTREMITY

By

Gary F. Lusin

B.S., Montana State University, 1972

Presented in partial fulfillment of

the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1978

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Chairman, Board of Examiners

Dean, Graduate School

6-7-78

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ABSTRACT

Lusin, Gary F., M.S., June 1978 Physical Education

Reliability of a New Instrument and Techniques for Measuring Joint Range of Motion in the Lower Extremity (86 pp.)

Director: Richard L. Gajdosik

The purpose of this study was to determine the reliability of the Phillips biometer along with the techniques established for its use in measuring joint range of motion and flexibility of selected rotation movements in the lower extremity. Specific techniques were developed pertaining to body segment stabilization, starting position, instrument placement, and body segment movement for each measurement.

Both extremities of fifteen male subjects were measured. Measurements included external and internal hip rotation with the hips extended, external and internal hip rotation with the hips and knees flexed, external and internal rotation of the leg on the thigh, hamstring tightness, and subtalar joint inversion and eversion for a total of nine measurements. Data were collected through test and retest trials conducted on the same day with one-half hour between trials. No excessive lower extremity activity was permitted the day of data collection, especially during the one-half hour between trials. An instruction session was held the day before data collection to familiarize the subjects to measurement procedures and the movements measured. Correlation coefficients were determined for each measurement. They ranged from .718 to .988. Five measurements obtained correlation coefficients above .90, three above .80, and one of .718.

It was concluded that the Phillips biometer and the techniques established for its use could measure the selected rotation movements in the lower extremity with a high degree of reliability. Control of measurement technique factors was essential. Body segment stabilization was considered the major factor to control to obtain measurement readings for distinct joint motions.

ACKNOWLEDGMENTS

I am indebted to Mr. Richard Gajdosik whose untiring patience, understanding, and interest directed me through a truly educational experience that has sparked my interest to continue to research the concepts presented in this paper. His constant support made the completion of this paper an enjoyable experience.

A special thank you to the following individuals for their support and assistance:

Dr. Jack Bruckner for his medical assistance and knowledge of sports medicine in reviewing this paper;

Dr. Gary Nygaard for his help in the methods and techniques of research;

Dr. Kathleen Miller and Dr. John Dayries for their close and careful reading of my paper and fine comments for its improvement;

Dr. Robert Phillips who developed the biometer and initially introduced me to it and the concepts behind its development;

Mr. Vince Wilson for his academic interest and suggestions through the course of this study.

Thank you to the subjects who cooperatively gave their time so the measurement techniques could be established and tested.

Thank you also to Mr. David Wilson (subject) and Mr. John Krempel (photographer) whose time and assistance made the photographs within this paper possible.

Finally and most importantly, to my wife, Mary Jo, whose personal, professional, and financial support has provided me the opportunity to establish a career of my choice. To her, I dedicate my future.

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CHAPTER I

INTRODUCTION

Recently, interest has expanded regarding joint range of motion and flexibility. Attempts are being made to measure very specific joint ranges of motion and apply them to flexibility. Measuring devices and techniques have been developed that are capable of measuring range of motion in all joints (17,18). Others have been designed to measure a single range of motion for a specific joint (11,18). Few have been determined to be reliable measures of joint motion. The instruments found to be reliable are subject to question because of their body segment stabilization techniques, instrument placement, and location of joint axis. Goniometric measurements are generally recognized as more accurate and reliable than subjective judgments, as estimating visually without assistance, but are still considered "grossly quantitative" (4,13). The measurements obtained do not express precise quantitative data.

The major consideration and perhaps the most difficult step in the technique of goniometry is locating the joint axis about which the movement being measured is occurring (3,8,9). Moore (17) stated that "the axis of motion appears to shift as normal motion progresses." Moore (18) also stated that "since the true axis of motion is located at the intersection of the two limbs of the angle, this cannot be determined until the end of the desired movement." It is extremely important when using a universal type goniometer that the correct intersection of the limbs be found. This allows for the correct joint axis used in measuring joint motion or flexibility.

Harris (8) stated that the literature supports the premise that flexibility, determined by joint range of motion, is highly specific to separate joint actions or combinations of actions. Therefore, instrumentation and techniques must be established to measure specific joint motion.

A new instrument, the "Phillips Biometer" (Fig. 1, p. 72) and definite techniques for its use, have been developed to measure specific joint ranges of motion and flexibility in the lower extremity. This is accomplished by the biometer being attached in a vice-like fashion to bony landmarks thereby expressing joint motion through the bone or body segment directly involved in the motion.

Techniques established to control body segment stabilization and instrument placement allowed the biometer to account for the change in axis of motion throughout a movement.

Purpose of the Study

The purpose of this study was to determine the reliability of the Phillips biometer and the techniques developed for its use in measuring joint range of motion and flexibility of selected rotation movements in the lower extremity. The techniques included body segment stabilization, starting position, instrument placement, and body segment movement for each measurement. Instrumentation and measurement techniques were inseparable in determining specific joint ranges of motion or flexibility.

Need for the Study

A study to determine the reliability of the Phillips biometer and the measurement techniques developed was necessary to establish a basis for further research in the area of athletic injuries to the lower extremities. The Phillips biometer was developed to measure selected rotation movements in the lower extremities and determine the relationships of those movements, or combination of movements, to specific musculoskeletal injuries such as shin splints, achilles tendonitis, ankle sprains, etc.

The general questions to be investigated in further research are: Are there factors, as determined by selected rotation movements, that predispose athletes to certain injuries? Do persons who repeatedly sprain their ankles (or any other injury) possess different amounts of rotational movement or joint motion throughout the lower extremities than those who participate in similar activities but rarely sprain their ankles? If so, what are the movements and in what possible combinations do they exist? Are there certain ranges of motion for each movement that would enable a person to function injury-free (excluding injury caused by direct contact)? Before proceeding with investigations to determine whether certain lower extremity motions exist that can be used as possible predictors of lower extremity injuries, specific measurement techniques and procedures of use for the Phillips biometer must be developed and established as reliable.

Delimitations

This study was limited to male students enrolled in all Physical Education classes during the Summer and Fall quarters (1977) at the University of Montana. Ages ranged from twenty-one to thirty-one years. The study was further limited to students available between the hours of twelve o'clock p.m. to four o'clock p.m., Monday through Friday, for data collection.

All movements performed by the subjects were limited to active movements.

Limitations

While implementing the measurement techniques free oscillation of the pendulum dial of up to five degrees during light myclonus movements or quivering movements required estimation of the exact degree reading. This factor, found in only a few of the measurements, may have influenced the results.

Skin movement, over the area to which the biometer was attached, may have occurred during the performance of the motion measured and may have influenced the results. This was observed primarily during external rotation of the leg on the thigh.

Description of Terms

The following terms are described as they were used in this study:

Active Movement (motion). A movement produced by the person's own muscles (5). The subjects produced all movements and were unaided by any external force.

Forceful Straining. After reaching the end range of motion, as established in this study, further motion could be attained by exerting additional active movement. The additional active movement beyond the end range caused the extremity to shake and instituted substitution movements in the effort to produce further motion. The additional active movement is referred to as forceful straining and was unwanted motion in this study.

Myoclonus. The occurrence of regular, rhythmic contractions of a muscle subjected to sudden, maintained stretch (7).

<u>Quivering Movement (motion)</u>. A shaking or trembling of a body part or parts that occurred in starting positions as well as toward the end range of motion for some movements.

<u>Substitution Movement (motion)</u>. Movement produced by adjacent body parts in the unconscious effort to assist another body part to complete a specific movement. Since this study measured specific movements of body segments, influential movement produced by other body segments was unwanted.

CHAPTER II

SURVEY OF RELATED LITERATURE

The literature contains many studies pertaining to goniometry, the measurement of joint motion, and flexibility. The majority are concerned with the use of the universal goniometer while a few deal with special instruments and techniques for measuring specific joints. Most of the information known today regarding goniometry is contained in several investigations (4,8,9,16,17,18). These studies include extensive reviews of the literature, standard techniques of goniometry, and various other aspects of measuring range of motion.

So that the reader may understand the instrumentation and technique of goniometry, this review is presented in the following format:

1. Definition of Goniometry
2. Instrumentation
3. Numerical Expression
4. Starting Position
5. Axis of Motion
6. Summary

Definition of Goniometry

Goniometry is the use of instruments for measuring range of motion in the joints of the body (16). Discussion of goniometry in the literature has been increasing since the turn of the century. It was used extensively during World War I and World War II. Valuable information was provided to physicians and therapists concerning patient progress regarding range of motion of injured joints and related structures. This information also "aided in securing and maintaining patient interest and in further stimulating the desire to improve" (16).

Goniometry, although considered grossly quantitative, is still a more reliable estimation of joint motion than simple visual estimation, but it does provide some objectivity to the measurement of joint range of motion (9).

The first extensive review of goniometry was conducted in 1939 by Weichec and Krusen (28). In 1949, Moore presented a series of investigations pertaining to goniometry (9,16,17). This series consisted of an extensive review of the literature and investigated measurement techniques and the reliability of goniometry. Moore's investigation critically analyzed goniometry to determine if it provided accurate and reliable information concerning joint motion. Factors such as determining the true joint axis and proper instrument placement remained as questionable variables. Since Moore's investigation, additional studies have demonstrated increasing sophistication of instrument design and research methodology (18).

Instrumentation

Instruments designed to measure joint motion fall into two general classifications. The first is the tool of universal application. It can be used on all joints of the body for obtaining range of motion measurements. The second classification consists of instruments designed for measuring a single range of motion for a specific joint. These vary in size and shape and are designed to fit the contour of the adjacent body parts or they are applied directly to the lateral surface of the joint (8,16).

The most widely used instrument is the manual universal goniometer. It consists of a protractor which has two long slender arms or levers attached to its center (18). One of the arms is fixed and the other arm is movable. It is universally adaptable to all joints and can be used on all types of patients (17).

Moore (18) cited 36 publications that present many variations of instruments designed to measure joint motion. Many of the instruments developed are similar to the protractor-like universal goniometer. The proctrctor has been mechanically modified by many authors to fit their needs of measuring joint motion. Defibaugh (4) stated that "each author who has modified it points out the specific advantage his modification has over the protractor modifications of other authors." These modifications have been designed to measure specific joint motions. Defibaugh (4) briefly discusses methods of visual estimation, radiography, photography, schematography and outline tracings, trigonometry, and goniometry for measuring joint range of motion. Harris (8), Defibaugh (4), and Moore (16,18) cited many of the instruments and techniques that have been designed to increase the accuracy of measuring joint motion.

A number of instruments have been designed to measure lower extremity motion. Moore (18) cited many of these instruments and stated that they closely resemble the manual universal goniometer but are modified to measure specific lower extremity joints. Harris (8) cited an electrogoniometer (elgon) developed by Karpovich which is a goniometer with a potentiometer substituted for the protractor. Its main advantage is its ability to measure joint motion during activity. However, Karpovich and others have stated some difficulties with the elgon in the extreme ranges. At present there are a few joint actions that can be measured with the elgon (8).

Leighton (11,12,13,14) designed an instrument of the pendulum type which uses gravity as its origin and is attached to the body part being measured. The instrument, named the "Leighton Flexometer," eliminates the concern of establishing the true axis of motion within the joint. Therefore, error due to placement of the instrument directly over the axis of the adjacent limbs forming the joint is eliminated. Harris (8) stated that the Leighton flexometer "appears to be the most objective instrument for measuring joint action." Reliability coefficients established by Leighton (11) ranged from .899 to .997 for test-retest of two trials. Twenty-one measurements were conducted in the original study and fifteen had reliability coefficients greater than .970. Due to the established reliability of the Leighton flexometer additional studies on flexibility have been conducted (1,6,19,20) and some have been conducted by Leighton (12,13,14).

Numerical Expression

Moore (16,18) discussed three systems of numerical expression used in goniometry. "The three systems are dissimilar enough to make interchange of values impracticable" (11).

The first system is based on a scale of 0 to 180 degrees and has been adopted by the American Orthopedic Association, the American Society for Surgery of the Hand, endorsed by the American Medical Association and the Veterans Administration, and taught by most physical therapy schools in the United States. According to this system the anatomical position places the joints at zero degrees at which point motion begins and progresses toward 180 degrees. As motion progresses the numerical expression is recorded in positive numbers. In the case of a joint with restricted extension, the numerical expression decreases as the joint improves (16).

The second system is "based on the goniometric consideration that 180 degrees is the true expression to the half circle or the sum of two right angles" (18). In this system flexion approaches zero degrees and extension is limited to 180 degrees.

The third system using the full circle of 360 degrees never achieved popularity. This system was objected to because it presented large numbers, for example, 210 degrees of shoulder extension.

Starting Position

The initial step in precise goniometry is to place the subject in a specific body position (16,18), frequently called a "preferred starting position." Careful selection of the preferred starting position lessens the difficulty of isolating the desired arc of motion. The goniometer at this point can be positioned with greater accuracy since the position of the subject is less likely to deviate. This allows substitution movements in adjacent joints to be easily recognized and avoided.

Standardization of the preferred starting positions for all measurements is essential in a clinical situation. If a person is physically unable to assume the preferred starting position it must be stated as such. Exact anatomical positions must be recorded to assume standard goniometric measurements. Moore (16) expressed precisely the importance of establishing and standardizing preferred starting positions. She stated:

> It is well to use the anatomical position as a point of reference for the discussion of the technic of goniometry. It is universally understood, standard nomenclature. However, it is extremely valuable to give clearly and specifically the preferred starting position for the measurement of every movement. This should include the exact positions of all anatomical parts that may participate in or influence indirectly the movement to be measured. By so doing standardization of procedure is approximated and both intra-individual and inter-operator variances are reduced.

Axis of Motion

Many authors consider location of the axis of motion the single most important aspect of the technique of goniometry (3,8,9,11,16,17,18,27). The universal goniometer requires the establishment of the joint axis, preferably the true joint axis, to produce reliable joint motion measurements. The protractor must be placed over bony landmarks that are presumed to be the axis of the joint. An example is the lateral malleolus at the ankle being specified as a key axis location for dorsiflexion and plantarflexion (27). Moore (18) cited several studies that indicate no landmark is or can be a fixed axis of motion.

Instruments that can be attached to body segments and that utilize gravity as their origin are not concerned with the establishment and placement of the instrument to correspond with the joint axis (11). Critical establishment and maintenance of body segment stabilization techniques are essential in the use of a gravity controlled instrument. Since the axis of motion shifts as motion progresses (16,18), it is not necessary to consider the direct correspondence of the instrument and the joint axis when using a pendulum-type goniometer. Therefore, elimination of the need to establish the joint axis, as with protractor goniometry, should provide more reliable interpretations of joint motion.

Summary

The literature indicates that more objective techniques and instrumentation should be developed to measure specific joint motions and flexibility. Techniques developed for using the manual universal goniometer, and the Leighton flexometer, are not specific enough to measure distinct and separate joint motions, especially lower extremity rotation movements. Every aspect of joint motion, as well as adjacent joint and body segment motion, must be analyzed to develop logical, complete and objective techniques for measuring specific joint movements.

CHAPTER III

METHODS AND PROCEDURES

Subject Selection

The subjects consisted of volunteers from courses randomly selected that were offered during the second Summer Session (1977) and Fall Quarter (1977) by the Department of Health and Physical Education at the University of Montana. The data was collected in the Pre-physical Therapy Complex at the University of Montana.

The subjects volunteered with knowledge of the following criteria pertaining to the study:

1. No limitations were placed on the subjects concerning past lower extremity injuries (fractures, surgery, sprains, etc.). Both extremities were measured.
2. All movements were performed actively. A procedure instruction session was held to familiarize the subjects with the movements and positions.
3. The test and retest was conducted on the same day between the hours of 12 p.m. and 4 p.m. Two subjects were scheduled for each afternoon.

4. Activity was restricted to normal daily activity the day of the measurements. Normal activity was considered routine but not excessive. Subjects were asked to refrain from any excessive activity the morning of the measurements. This included running, jogging, bicycling, and similar activities that required exertion of the lower extremities. All subjects relaxed in the supine position for thirty minutes between the test and retest trials to eliminate body warm-up from activity as studies indicate that warm-up immediately preceding movement increases the range of movement possible (2,4,12,15). This was included primarily for standardizing testing procedures.

The subjects had a mean age of 25.8 years, a mean height of 176.67 centimeters, and a mean weight of 80.27 kilograms. Ranges of subject height, weight, and age are available in Appendix A.

Instrumentation

The instrument used in this study was a pendulum-type goniometer that used gravity as its origin. It was developed by Dr. Robert L. Phillips, a podiatrist in Great Falls, Montana, and was named the "Phillips Biometer." The instrument was designed to measure lower extremity joint motion by being attached directly to bony prominence or prominent extremity surfaces.

Two aluminum arms (Fig. 3a & 3b, p. 72) were attached perpendicularly to a durable plastic support arm (Fig. 3d, p. 72). Both aluminum arms slid freely along the plastic support arm and could be secured at any position by tightening the set screws at the top of each piece. Permanently attached to one of the aluminum arms was a pendulum dial which indicated degrees of motion (Fig. 3c, p. 72). Attached to each aluminum arm was a small aluminum cup-like device which was free to slide up and down the arms and could be secured at any position by tightening set screws (Fig. 3e, p. 72). The ability to secure various parts of the device at any position allowed the biometer to be adapted to any size extremity (Fig. 1 & 2, p. 72). The protractor (Fig. 3f, p. 72), an integral part of the biometer, is used for other measurements of the lower extremity but was not used in this study. Therefore, the entire capacity of the instrument was not utilized.

Group Testing Procedures

Each subject was informed of the guidelines established and fully understood the movement techniques required prior to the actual collection of data. They also read and signed the volunteer consent form (Appendix B). To standardize the testing procedures the following guidelines were established.

All subjects were scheduled for two sessions. The first was an instruction session and the second was a test-retest session for data collection. The instruction session was designed to familiarize the subjects with the testing procedures and specific movements required for each measurement. The session also served to caution the subjects of substitution movements that may occur during each specific movement and to instruct them how to eliminate unwanted motions. Substitution movements were viewed as variables that could influence the degree of motion measured. It was specifically emphasized that no lower extremity activity could be permitted the morning of data collection.

Since all movements were performed actively, it was necessary for the subjects to control the substitution movements as well. Instruction regarding movement technique and active control of unwanted substitution movements was considered adequate for body segment stabilization for several of the measurements.

The second scheduled session consisted of the test and retest trials. This session was scheduled during the afternoon on the day following the instruction session. All subjects were measured between 12:00 p.m. and 4:00 p.m., depending on the subject's class schedule. Two subjects were scheduled each day.

All subjects relaxed on beds in the supine position for five minutes prior to the test trials. One-half hour was allotted for the test and one-half hour for the retest. Between the test and retest trials all subjects relaxed in the supine position for one-half hour. No lower extremity activity was allowed during the rest period and the subjects were not allowed to sleep.

A hard-surfaced wooden table was used for all examinations. All subjects wore loose fitting gym trunks to allow freedom of movement at the hip joints. Room temperature varied from 73 degrees Fahrenheit to 76 degrees Fahrenheit during the course of data collection.

A total of nine measurements were taken. They were separated into those taken in the supine position and those taken in the sitting position.

Supine position measurements included:

1. External hip rotation with the hips extended
2. Internal hip rotation with the hips extended
3. External rotation of the leg on the thigh
4. Internal rotation of the leg on the thigh
5. Hamstring tightness

Sitting position measurements included:

1. External hip rotation with the hips and knees flexed
2. Internal hip rotation with the hips and knees flexed
3. Subtalar joint inversion
4. Subtalar joint eversion

The measurements were administered in the same order for both the test and retest as presented in the single testing procedure. Both extremities of all subjects were measured using the same technique for each extremity. This enabled each extremity to be considered as a separate subject for the purpose of data collection. Prior to actual data collection, 540 measurements were conducted to establish examiner consistency in measurement technique and to develop specific instructional commands for the subjects (details presented in Appendix D). Data collected during this session was not included in data analysis for this study. Similar, but revised techniques were used for the data collection.

A total of 540 measurements were taken on 15 male subjects (30 extremities) and were used for data analysis. All movements were performed actively. The subjects were instructed to perform the desired movement as far as possible without producing substitution movements or eliciting any forceful straining to gain further motion. These were the established limits of the end of range in this study. The subjects performed the desired movements slowly and steadily until the body segment could not be moved further. For all movements the subjects were cautioned against eliciting a myoclonus movement at the end of the body segment range. The subjects were instructed to tell the examiner when the motion was completed. The degree of movement was then recorded on the data collection sheet (Appendix C). The subject then returned the extremity to the zero degree starting position.

Once the biometer was placed in the desired starting position the cupped clamps were outlined on the extremity to allow identical replacement of the instrument for the retest measurement (Fig. 4 & 5, p. 74). A Flair pen was used because the fine line it produced enabled specific replacement of the instrument.

Single Testing Procedure

External hip rotation with the hips extended. Starting position (Fig. 6 & 7, p. 76): The subject assumed a supine position on the examination table. A firm wedged pad, fixed to the table, was placed under the hips with the thickest part (2 cm) lying across the coccyx, and the thinnest part (1 cm) extending to the upper lumbar region of the spine. This placed the pelvis in a slight posterior tilt and the hips extended slightly greater than zero degrees. The major purpose of the pad was for the comfort of the subject. A cloth strap was placed over the anterior superior iliac spines and secured under the table. This stabilized the pelvis by holding it securely to the pad and table and also maintained the pelvic tilt and eliminated rotation during the measurement. The biometer was secured to the femoral epicondyles while the patella was horizontal to the plane of the table and the cupped clamps were outlined on the skin.

Movement: With the instrument and subject secured, the examiner grasped the extremity by the heel and elevated it until the hip joint approached approximately zero degrees (Fig. 6, p. 76). The amount of elevation required to place the hip joint near zero degrees was determined by performing the movement on several subjects. This procedure was verified with a universal goniometer and allowed the examiner to subjectively place the hip joint near zero degrees during the data collection trials. The subject then externally rotated the extremity to the limits established (Fig. 8, p. 76).

Note: During the movement no pelvic or trunk rotation was allowed. The knee of the extremity was in complete extension throughout the movement.

<u>Internal hip rotation with the hips extended</u>. Starting position (Fig. 7, p. 76): The subject stabilization and instrument placement techniques remained unchanged from external hip rotation with the hips extended. A zero degree reading on the biometer dial was established by having the subject internally rotate the extremity from the externally rotated position until the dial showed zero degrees. This placed the extremity in the same starting position as that established for external hip rotation.

Movement: From the starting position the subject internally rotated the extremity to the limits established (Fig. 9, p. 76).

Note: No pelvic or trunk rotation was allowed. The knee of the extremity was in complete extension throughout the movement.

External rotation of the leg on the thigh. Starting position (Fig. 10, 11, 12, p. 78, Fig. 13, p. 80): The subject was supine and the extremities remained extended. A line was drawn across the anterior thigh seven centimeters above the superior aspect of the patella and an additional line was drawn on the apex of the anterior thigh perpendicular to the transverse line. Thus a cross was formed on the anterior aspect of the thigh seven centimeters above the patella and served as a reference for maintaining the extremity in the starting position (Fig. 11, p. 78). A thin wire attached to a metal framed standard was positioned to cross the anterior thigh a few centimeters proximal to the distal end of the femur. Suspended from the top of the metal framed standard was a plumb-line which hung perpendicular to the wire and extended approximately four inches below it. This served as a stationary reference and allowed the subject to maintain the extremity in the starting position.

The hip and knee of the extremity measured were flexed to approximately 90 degrees each. The examiner supported the leg at the heel thereby maintaining knee flexion. The biometer was secured to the leg just distal to the head of the fibula laterally and to the flattened area on the tibia slightly below the medial condyle (Fig. 14 & 15, p. 80). The cupped clamps were outlined on the skin. With the instrument secured, the extremity was positioned to produce a zero degree reading on the biometer (Fig. 11, p. 78, Fig. 13, p. 80). The subject then moved the plumb-line along the wire until it intersected the reference lines on the anterior thigh at which time the extremity was held in this position (Fig. 11). Thus, the starting position following instrument placement consisted of the hip and knee flexed to approximately 90 degrees each with the leg supported by the examiner at the heel. The reference lines on the anterior thigh corresponded to the stationary reference lines formed by the wire and the plumb-line and a zero degree reading established on the biometer. At this point it was important that the subject maintained his head in the same position throughout the movement. A change in head position altered the perspective of the starting position established by the reference points.

Movement: The subject externally rotated the leg on the thigh to the limits established (Fig. 14, p. 80). Observing the biometer rotate with the leg provided the subjects with visual feedback of the movement and allowed them to achieve the greatest amount of rotation possible. Maintaining the external rotation movement, the thigh was repositioned to the original starting position by aligning the reference points as they were originally. This eliminated the influence of thigh abduction or adduction that may have occurred during the external rotation of the leg.

Note: The subject did not move his head once the extremity was in the starting position and the reference points established. The subject maintained the alignment of the reference points throughout the movement. If the thigh abducted or adducted during the movement it was repositioned to the original starting position. The examiner supported the leg at the heel and was careful not to introduce assistive rotation to the movement. No hip flexion, extension, abduction, adduction, internal or external rotation was allowed beyond the original starting position.

<u>Internal rotation of the leg on the thigh.</u> Starting position (Fig. 13, p. 80): The femur was positioned in accordance with the reference lines used for external rotation of the leg on the thigh. The instrument remained secured in the same position. The starting position was established by the subject aligning the reference points and relaxing the leg to obtain a zero degree reading on the biometer dial. The leg continued to be supported at the heel by the examiner.

Movement: The subject internally rotated the leg on the thigh using the biometer as a visual reference to achieve the greatest amount of movement (Fig. 15, p. 80). The subject repositioned the thigh in the original starting position while maintaining internal rotation of the leg.

Note: The same cautions were observed as those for external rotation of the leg on the thigh. No hip motion beyond the original starting position was allowed.

<u>Hamstring tightness</u>. Starting position: A line was drawn on the lateral aspect of the leg between the head of the fibula and the most prominent aspect of the lateral malleolus (Fig. 5, p. 74). This represented the longitudinal axis of the leg. The arm of the biometer containing the pendulum dial was placed along the axis and held in place with two elastic straps with velcro fasteners (Fig. 17, p. 82).

The subject was supine and the extremity not measured was strapped to the table in complete extension. The extremity measured was positioned with the femur in the sagittal plane. The examiner positioned the hip at approximately 90 degrees flexion. The lateral epicondyle and greater trochanter were used as references to aid in this positioning. With the thigh positioned, the metal framed standard was moved so the cross wire made contact with the anterior thigh. The subject actively maintained contact of the thigh with the wire.

Movement: The subject actively extended the knee slowly and steadily while the thigh maintained contact with the wire (Fig. 16 & 17, p. 82). The subject indicated the end of movement and the reading was recorded.

Note: During the movement the anterior thigh remained in contact with the reference wire to maintain 90 degrees hip flexion, and the femur remained in the sagittal plane. The ankle was relaxed in slight plantar flexion. It was extremely important that the knee was extended as far as possible without forceful straining and not to the point of eliciting a myoclonus movement.

External hip rotation with the hips and knees flexed. Starting position (Fig. 18 & 19, p. 84): The subject was seated on a small portable chair placed on top and centered at one end of the examination table. It was adjusted back and forth to accommodate the varying femur lengths between subjects. All subjects measured 8 centimeters from the end of the table to the head of the fibula. One and one-half inch adhesive tape was positioned on the table top and allowed for marking the proper chair position for each subject. The back of the chair was secured at 90 degrees in relation to the chair seat. All subjects sat with the low back and upper buttock region as far back in the chair as possible. This position placed the hip joint in 90 degrees flexion. A two-pound sandbag was positioned on the table and under the distal end of the femur. This helped maintain the approximate 90 degrees hip flexion.

A metal bracket forming a 90-degree angle was positioned with one side on the table top and the other side perpendicular to the table top and resting against the lateral aspect of the thigh. This arrangement served as a guide to help maintain the femur in the sagittal plane and thus prevented abduction. A cloth strap was placed across the anterior superior iliac spines of the pelvis and secured under the table which eliminated pelvic elevation resulting from the hip rotation movement. The subjects also grasped under the edges of the table top and pulled upward. This forced the pelvis into the chair resulting in additional stabilization against pelvic elevation.

The biometer was secured to the femoral epicondyles and the cupped clamps were outlined on the skin. The extremity was allowed to relax and assume the normal amount of internal or external hip rotation in this sitting position. The starting position was then established by the degree of rotation displayed by the biometer with the extremity in the relaxed position (Fig. 19, p. 84). The degree of motion was determined from this starting position to the end of movement.

The extremity not measured was extended at the knee and supported on a chair (Fig. 18, p. 84). This allowed the extremity measured to be rotated externally without limitations from the other extremity.

Movement: By establishing the knee as the pivot point the leg was arched medially thereby producing the desired external rotation in the hip joint (Fig. 20, p. 84). The movement was performed without incorporating substitution movements or forceful straining.

Note: The thigh remained in the sagittal plane with no hip abduction or adduction. Hip flexion or lateral trunk flexion was not allowed. Subjects were instructed to maintain equal pressure on the ischial tuberosities.

Unequal pressure indicated pelvic elevation.

Internal hip rotation with the hips and knees flexed. Starting position (Fig. 19, p. 84): The subject and instrument remained in the same placement as for external rotation of the hip with the hip and knee flexed. The extremity measured was allowed to relax thereby initiating the internal rotation movement from the same starting position as that for external rotation.

Movement: With the knee acting as the pivot point the leg was arched laterally thereby internally rotating the hip joint (Fig. 21, p. 84). The movement was performed without incorporating substitution movements or forceful straining.

Note: The thigh remained in the sagittal plane with no hip abduction or adduction. Hip flexion, lateral trunk flexion or pelvic elevation was not allowed. Subjects were again instructed to maintain equal pressure on the ischial tuberosities. Unequal pressure indicated pelvic elevation.

Subtalar joint inversion. Starting position (Fig. 22 & 23, p. 86): The subject remained seated and secured in the same position required for external and internal hip rotation with the hips and knees flexed. Metal brackets, each forming a 90-degree angle, were clamped to the table on either side of the leg measured. One side of the bracket protruded from the table perpendicular to the longitudinal axis of the leg. Each bracket was positioned so the protruding sides clamped and secured the leg in the sagittal plane.

The subject actively dorsiflexed the ankle as far as possible. The biometer was clamped to the inferior aspect of the calcaneus near the apex of the heel (Fig. 22, p. 86). This was in a position distal and posterior to the subtalar joint axis of inversion and eversion. It was clamped to produce a zero degree reading on the biometer dial. An outline of the cupped clamps was drawn on the skin as reference marks for placement for retest measurements.

Movement: The ankle was dorsiflexed as far as possible. It was then inverted as far as possible (Fig. 24, p. 86). The degrees of motion indicated on the biometer dial represented the inversion movement in the subtalar joint.

Note: It was important that the subject eliminate all hip motion, with special attention given to movement resulting from hip external rotation. This specific motion transferred to leg adduction and could influence the degree reading. It was also important that the subject maintain maximal dorsiflexion throughout the movement.

<u>Subtalar joint eversion</u>. Starting position (Fig. 23, p. 86): The subject remained seated and secured as for subtalar joint inversion. The biometer also remained in the same placement as for subtalar joint inversion.

Movement: The ankle was dorsiflexed as far as possible. It was then everted as far as possible (Fig. 25, p. 86). The degree reading on the biometer was that produced in the subtalar joint due to eversion.

Note: It was important that the subject eliminate all hip motion, with special attention given to movement resulting from hip internal rotation. This specific motion transferred to leg abduction and could influence the degree reading. It was also important that the subject maintain maximal dorsiflexion throughout the movement.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

ANALYSIS OF RESULTS

Data from this study were analyzed using the Pearson product-moment correlation coefficient (r) (26). Table 1 indicates the correlation coefficient obtained for each of the nine measurements. Table 1 also includes the means for the left and right lower extremities, the standard deviations for each extremity, and the predictive index of the measurements. Statistical data, other than the reliability coefficients, was presented only to further interpret the coefficients obtained.

The coefficients obtained in this study represent the reliability of the instrument and techniques developed for its use in measuring joint motion in the lower extremity. All measurements demonstrated a high degree of reliability with measurements having an r above .90 demonstrating a very high correlation (25).

DISCUSSION OF RESULTS

The Phillips biometer and the techniques developed for its use in measuring lower extremity joint range of motion

TABLE 1

RELIABILITY COEFFICIENTS, MEANS, STANDARD DEVIATIONS, AND THE PREDICTIVE INDEX FOR EACH MEASUREMENT

Measurements	r	Left extremity means*	SD	Right extremity means*	SD	Predictive Index
External hip rotation with hips extended	.911	32.4	7.96	37.7	7.66	.588
Internal hip rotation with hips extended	.946	20.7	7.32	15.9	7.10	.676
External rotation of leg on thigh	.805	9.0	3.47	8.5	3.52	.407
Internal rotation of leg on thigh	.925	7.8	3.51	8.9	3.67	.621
Hamstring tightness	.988	30.9	16.95	31.4	16.83	.845
External hip rotation with hips and knees flexed	.880	25.2	4.15	24.1	5.34	.525
Internal hip rotation with hips and knees flexed	.988	22.8	6.49	23.1	7.44	.845
Subtalar joint inversion	.896	12.8	5.48	13.5	4.19	.556
Subtalar joint eversion	.718	8.8	3.21	9.3	3.10	.304

*Test and retest degree readings were combined to establish means for the left and right extremities respectively.

were found to be highly reliable (subtalar joint eversion moderately reliable). The measurement techniques were developed to control variables and provide a relatively simple method of using the Phillips biometer.

Since this study investigated the reliability of the instrument and measurement techniques, it is important to discuss the variables inherent to each. They included variables for which the investigator and the subject were responsible for controlling which contributed to the objectivity of measuring joint range of motion or flexibility. These variables were investigated and procedures developed to control their influence on joint motion measurements.

The influence of the variables involved will be discussed in the following manner:

A. Instrument Influences
   1. Placement
   2. Oscillation and reading of the dial
   3. Skin movement during the measurement

B. Measurement Technique Influences
   1. Starting position
   2. Axis of motion
   3. Body segment stabilization
   4. Intrinsic factors
   5. Instruction session influence

Instrument Influences

Placement. Consistent instrument placement and replacement was important to control and was the responsibility of the investigator. To segregate a joint's movement into external and internal rotation required consistent replacement of the instrument. This was achieved by outlining the cupped clamps on the skin once the instrument was secured for the test trial. A Flair pen was used to outline the cupped clamps. The distinct line exhibited by the pen enabled accurate replacement of the instrument for the retest trials.

Measurements such as external and internal hip rotation with the hips extended and with the hips and knees flexed allowed placement of the instrument securely to the femoral epicondyles. These are distinct bony prominences and placement of the cupped clamps over them was consistent. However, outlining the clamps assured that the instrument was placed in the same position for both trials.

Measurements other than the hip rotation measurements did not allow the instrument to be secured to such distinct bony prominences. It was therefore necessary in those measurements to control the variable of instrument replacement closely. The hamstring tightness measurement was the only measurement that did not require securing the instrument with the cupped clamps. However, a reference line representing the longitudinal axis of the leg was necessary for replacement of the appropriate instrument part (Fig. 5, p. 74).

It is believed by this investigator that identical instrument placement is essential to achieving consistent range of motion measurements. External markings provided an objective method of replacing the instrument consistently.

<u>Oscillation and reading of the dial</u>. A second instrument variable that may have contributed to the difference between the test and retest trials was oscillation of the degree indicator of the pendulum dial. One source of oscillation was produced by a quivering of the extremity at the end of the range and was not a myoclonus type of movement. Some subjects elicited the quivering motion at the beginning of the movement in an apparently relaxed position. The investigator observed that subjects who elicited the quivering motion did so to varying degrees for all measurements. The quivering movement would always originate in the body segment or joint proximal to the point of instrument placement.

External and internal hip rotation with the hips and knees flexed and subtalar joint inversion and eversion were measurements that demonstrated the quivering motion resulting in oscillation of the degree indicator. It was observed that some subjects exhibited the quivering motion while in the starting position and also at the end of the movement. These subjects were unable to control the quivering motion.

Another source of oscillation of the degree indicator occurred because of a myoclonus-type movement. The hamstring tightness measurement could have caused oscillation due to a myoclonus movement if the knee had been completely extended. However, measurement of hamstring tightness was designed to be taken immediately before the hamstring muscle group produced the myoclonus movement. Some of the subjects approached the end of the knee movement and could not control the myoclonus movement totally, resulting in oscillation of the degree indicator to a small extent.

The oscillation of the degree indicator on certain movements resulted in the examiner estimating the degrees of motion by determining the midpoint of the oscillatory range. The greatest oscillatory range was five degrees. This was found to occur in external and internal hip rotation with the hips and knees flexed and subtalar joint inversion and eversion.

After examining the reliability coefficients obtained for the nine measurements, the internal movements demonstrated the highest coefficients. This was believed due to a greater control of the variables involved between the test and retest trials. The internal movements also demonstrated the least amount of degree indicator oscillation which may have contributed to the higher reliability coefficients. This was not a major influential factor in determining the reliability of the Phillips biometer. Nevertheless, it presented a variable that could explain different results between test and retest trials.

<u>Skin movement influences</u>. Since the biometer was attached to the extremity over bony prominences and to body segments in a clamp-like fashion, the possibility of skin movement existed during the measurements.

It was observed that external and internal rotation of the leg on the thigh elicited some skin movement that may have influenced the degree readings to a small extent. The biometer was not secured to definite bony prominences. Its stability during the rotation movements depended on the stability of the soft tissue over the bony segments to which it was attached. If skin movement was observed during these movements, it was observed to be initiated by a change in shape of the gastrocnemius muscle as the leg rotated on the thigh.

External rotation of the leg on the thigh resulted in greater gastrocnemius muscle action than internal rotation. The subjects demonstrated a greater ability to keep the gastrocnemius muscle relaxed during the internal rotation movement, resulting in essentially no observable skin movement.

External rotation of the leg on the thigh was the only measurement that was observed to have skin movement influence the degree reading and that only being a small influence. Therefore, the influence of skin movement upon the results of this study was considered minor by the investigator.

Measurement Technique Influences

Factors involved in measurement technique were discussed in many studies (3,8,9,11,16,17,18). In these studies important factors considered were starting position, axis of motion, and body segment stabilization. Control of these factors was influential in obtaining the range of motion measurements in this study.

Starting position. The starting position is considered the initial step in precise measurement of joint range of motion (16,18). This was particularly important in this study because the external and internal movements were considered distinct and separate motions. Therefore, it was essential the same starting position be established in the test and retest trials.

The cupped clamps were outlined on the skin to assure the same starting position for each trial. With the instrument replaced in the same position according to the external markings, the extremity was positioned to produce a zero degree reading on the biometer.

Axis of motion. The location of the axis of motion was considered the single most important technique of goniometry (3,8,9,11,16,17,18). This, however, applied to the technique used with the manual universal goniometer. Proper placement of the pivot point of the universal goniometer is essential for accurate joint motion measurement. This requires body landmarks to which the pivot point must be aligned. Moore (18) cited that no landmark is, or can be, a fixed axis of motion. This, combined with the fact that the axis of motion shifts as motion progresses (16,18) presents a major problem in using the manual universal goniometer to measure accurately and objectively specific joint ranges of motion as conducted in this study.

Pendulum-type instruments, which are secured to the body part moving through the arc of motion, are not concerned with establishment of the axis of motion (11). Any shift in the axis of motion as movement progresses is transferred through the body part directly involved in the motion. This is accounted for by the degrees of motion displayed on the instrument. The Phillips biometer is a pendulum-type goniometer, therefore, location of the axis of motion was not considered a factor that influenced the degrees of motion obtained in this study.

<u>Body segment stabilization</u>. It was important that proper body stabilization techniques be employed to assure measurement of specific joint motion and a return to the initial starting position. If controlled body stabilization procedures were omitted, reliable measurements could not be obtained.

The lower extremity is moved by many two-joint muscles which can produce various actions, or combinations of actions, on each joint they cross. They also function in specific patterns of movement in relation to other lower extremity muscles to produce coordinated, efficient motion. Measurement of a distinct joint motion required control of other motions (substitution movements) within the same joint or body segment as well as the adjacent joints or body segments. Control of the substitution movements was accomplished by extrinsic mechanical supports and by the subject's conscious control of the adjacent joint movements. Mechanical supports such as cloth straps or metal guides, were used wherever possible to produce more objective data. However, in some measurements it was necessary for subjects to control the adjacent body segment movements actively. Controlling the substitution movements throughout the ipsilateral and contralateral limbs and pelvis resulted in the measurement of distinct joint motions.

This investigator believes that body segment stabilization was the most important factor to control in this study and should be a major concern of any investigator using the universal goniometer or the Leighton flexometer.

Intrinsic Factors

Intrinsic factors refer to structure surrounding the joints such as muscles, tendons, and ligaments as well as the responsibilities of these tissues in performing the active movements, stabilizing adjacent body segments and limiting joint action. The relative effect muscles, tendons, and ligaments have on determining joint motion will be discussed. The importance of internal control of other joint movements will also be discussed. These factors were generally inherent to all subjects and their control was considered the responsibility of the subject.

Table 1 shows that the reliability coefficients obtained ranged from .718 to .988. It was observed that the coefficients of the internal movements were consistently higher than those for the external movements. Intrinsic factors, although not specifically observable, were believed to contribute significantly to the reliability coefficients obtained.

The end range of motion of the internal movements was considered one intrinsic factor that contributed to the consistent difference within the rotational movements. Internal structures limiting the motions were muscles, tendons, and ligaments. Muscle tissue displays the property of elasticity. Steindler (23) stated that the "only stress to which muscle, as a passive structure, is exposed is tension." He also stated that "when such tension is applied a passive elongation occurs." During the tests the muscles' limiting range of motion was passively elongated as the muscles performing the movement contracted. Steindler (23) stated that a "normal muscle fiber can be stretched to 1.6 times its original length before it ruptures." This points out that a wide range exists within which a muscle is capable of limiting motion as it is elongated. In other words, because of the elastic property of muscle tissue, muscles do not definitely limit motion unless elongated to a point beyond the elasticity of the muscle.

Tendons and ligaments are connective tissues and are composed primarily of collagenous fiber. Hollinshead (10) stated that "these fibers are essentially nonelastic" which would indicate that these structures provide a definite end point to joint motion.

Elasticity of muscle tissue and the nonelasticity of tendon and ligament tissue may partially explain why a more definite end point of motion was observed in the internal hip rotation movements. Hollinshead (10) stated that three major ligaments of the hip joint (iliofemoral, pubofemoral, and ischiofemoral) "have a common action in tending to limit internal rotation of the femur, as this would increase their spiral." He also stated that "external rotation tends to unwind their spiral and is therefore checked entirely by muscles."

High reliability coefficients were obtained for all hip rotation measurements. The measurements with the hips extended resulted in an r of .911 for external rotation and .946 for internal rotation. Measurements with the hips and knees flexed resulted in an r of .880 for external rotation and .988 for internal rotation. Although these coefficients were high, the latter (for external) coincide with Hollinshead's (10) statement that "all parts of the capsule are relaxed during flexion and external rotation of the thigh." Therefore, external hip rotation movements should exhibit a less definite end of motion, as observed in this study. This should especially be observed in hip rotation movements with the hips flexed which was also the case in this study.

Restriction by bone within the joint was not considered a factor in this investigation. It was believed that the movements performed were not forceful enough to cause restriction by bone and that soft connective tissue of ligament and muscle was the primary limiting element of motion in the hip joint.

The rotation measurements of the leg on the thigh showed that the internal movements resulted in an r of .925 as compared with .805 for the external movement. Objective anatomical reasons could not adequately explain this difference. However, comments by the subjects may partially explain the difference. Some of the subjects expressed difficulty in maintaining or returning to the exact starting position (refer to Fig. 11, p. 78).by aligment of the reference lines on the thigh with the plumb-line.

Considering the difference in the coefficients and the fact that the instrument was not moved between the internal and external movements, it is apparent that all variables related to the internal movement were more controllable than the external movement. This investigator cannot account for the relative contribution of each variable, but the variable of the starting position was observed to be difficult to return to once the movement had been completed. It is important to note that the starting position included positioning of the extremity as well as the head (refer to Starting Position, p. 22). A deviation in either one resulted in a different starting position the subjects returned to after completing the rotation movement.

Establishing, maintaining, and returning to the original starting position was difficult for all subjects. This was considered a significant variable to control in this measurement. It was also considered the major factor that influenced different results between the test and retest trials. This investigator observed, and this was supported by the subjects, that the internal rotation movement was "easier" to perform and resulted in the least deviation from the starting position.

Some subjects also stated that the instrument "pinched" their calf muscles as they performed the external rotation movement, thereby limiting their motion. The "pinch" was described as a restrictive feeling rather than a painful stimulus.

Subtalar joint inversion and eversion also demonstrated a higher reliability coefficient for the internal measurement. Subtalar joint inversion obtained an r of .896 and subtalar joint eversion obtained an r of .718. All subjects expressed some difficulty in performing the inversion and eversion movements. They consistently had difficulty in the eversion movement. Maintaining the hip joint in the starting position while performing the eversion movement was a common problem with all subjects. They introduced slight internal rotation of the hip during the eversion movement. This internal hip rotation transferred to abduction of the leg which increased the degree of the eversion movement. This investigator observed that the slightest amount of internal hip rotation resulted in a substantial increase in the amount of eversion motion shown on the biometer dial.

Control of the internal hip rotation was primarily the responsibility of the subject. It was extremely difficult to control during the eversion movement. Body segment stabilization procedures used for this movement controlled pelvic elevation and lower extremity adduction and abduction, but did not control internal hip rotation. Therefore, the subject's total concentration was essential in maintaining the lower extremity in the starting position and eliminating internal hip rotation.

Another factor that may have contributed to the greater reliability of the inversion measurements was the comparative strength of the invertor muscles. According to Steindler (23) the invertor muscles are approximately twice as strong as the evertor muscles. This may explain why several subjects stated that the inversion movement "felt more natural" than the eversion movement. This investigator also observed that the subjects controlled hip motion almost totally while inverting the subtalar joint.

The hamstring tightness measurement obtained a reliability coefficient of .988. This indicated that factors contributing to this movement were controlled and accounted for sufficiently to produce a near-perfect relationship between the test and retest trials. This measurement determined the tightness of the hamstring muscle group by its limitation on knee extension. The effect of the gastrocnemius muscle in limiting knee extension was excluded by having the subjects maintain the ankle in a relaxed, slightly plantarflexed position. Establishing and controlling the end range of movement was extremely important to the consistency of this measurement and was the responsibility of the subject. They were responsible for recognizing the end of the range each time the movement was performed. The end range was initially established in the instruction session.

The procedure used in this study for determining hamstring tightness required active extension of the knee joint. This resulted in gradual stretching of the hamstring muscle group. This group increasingly limits the amount of knee extension as the knee is extended. Toward the end of the knee extension movement the extremity began a myoclonus movement. The point established as the end range of movement of the hamstrings was at the initial feeling of tightness in the muscle group and immediately before the myoclonus motion was initiated. Once the subjects could perceive that point they were able to return to it repeatedly as the correlation coefficients have demonstrated. It was observed during the instruction session, while the end range point was being established, that letting the subjects go beyond that point produced an increase in myoclonus as would be expected. It also initiated movements such as hip extension which caused the thigh to move away from the reference wire thereby deviating from the established starting position.

Influence of Instruction Session

Because all movements in this study were performed actively, it was important that the subjects knew what movements were expected of them and how it "felt" to perform them. According to Sweigard (24) "understanding movement is the greatest contribution the cortex can make to effective and efficient subcortical planning of neuromuscular coordination to produce a desired movement." This means that for a person to perform a movement effectively and efficiently, that person should understand the movement. The instruction session served to help the subjects understand the movements performed. It provided them time to practice the movements and establish necessary visual and sensory feedback reinforcement. Sweigard (24) stated that "the brain must receive feedback of the progress and range of movement and of the change in muscle tension so that it can adjust to them to achieve the goal of movement."

This investigator believes the instruction session provided the subjects with an understanding of the movements that allowed them to perform the movements with the same ability for the test and retest trials. The subjects entered the data collection sessions with an understanding of the motions to perform, proper body stabilization procedures for each measurement, and appropriate visual and sensory feedback cues to assist in maximum performance of each movement. It also assisted them in recognizing and understanding the verbal commands used by the investigator for each movement.

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

SUMMARY

The purpose of this study was to determine the reliability of the Phillips biometer along with the techniques established for its use in measuring joint range of motion and flexibility of selected rotation movements in the lower extremity. Measurement techniques were developed with regard to body segment stabilization, starting position, instrument placement and body segment movement for each measurement. A total of nine measurements were conducted on each extremity. Thirty extremities were measured making the total number of measurements 540.

Fifteen male students volunteered from classes randomly selected that were offered in the Health and Physical Education Department at the University of Montana. The subjects were scheduled for two sessions. The first was an instruction session to familiarize the subjects with movements and measurement procedures. The second session was scheduled for the following day and data was collected. Each subject was measured twice, the first was the test and the second served as the retest. The correlation of these trials was determined by the Pearson product-moment correlation coefficient.

The results indicated the Phillips biometer and its measurement techniques could reliably measure selected rotation movements in the lower extremity. Correlation coefficients ranged from .718 to .988. Five measurements were above .90, three were above .80, and one measurement was .718.

Measurement technique factors of instrument placement, starting position, and body segment were important to control. However, the factor of body segment stabilization was considered by this investigator to be the most important factor to control in determining the degree of motion of specific rotation movements in the lower extremity.

CONCLUSIONS

The results of this study indicate the following conclusions:

A. The Phillips biometer and measurement techniques developed in this study for its use were found to be reliable in measuring selected rotation movements in the lower extremity.

B. Control of measurement techniques such as starting position, instrument placement, body segment movement through the desired range, and body segment stabilization was essential for measuring joint ranges of motion.

C. Stabilization of adjacent body segments and joints was considered the major factor to control in obtaining measurement readings for distinct joint motions.

RECOMMENDATIONS

Based on the results of this study, the following recommendations for further study are proposed:

A. To determine the reliability of the Phillips biometer and proper techniques for measuring movements passively in the lower extremity.

B. To determine the inter-investigator reliability of the Phillips biometer and measurement techniques.

C. To investigate the use of the Phillips biometer in measuring other selected movements (such as ankle dorsiflexion with the knee extended and flexed, relationship of the forefoot to the rearfoot, etc.) with objective, reliable measurement techniques.

D. To investigate the use of measurement technique procedures to make measurements more clinically feasible. This would involve reliability studies to determine which, if any, procedures (such as instruction session, external markings, or body stabilization, etc.) could be eliminated or reduced and still obtain high reliability coefficients.

E. To investigate the feasibility of using the Phillips biometer to measure rotation movements in the upper extremity.

Based on the results of this study, the following recommendation for instrument re-design is proposed:

A. The degree indicator filled and sealed with a clear viscoid fluid (light oil) to reduce the free oscillation of the pendulum dial during movement. Any other method of reducing oscillation should be considered also.

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APPENDICES

APPENDIX A

SUBJECT DATA INCLUDING AGE, WEIGHT, HEIGHT, WITH MEANS AND RANGES

TABLE 2

SUBJECTS AGE, WEIGHT, AND HEIGHT WITH MEANS AND RANGES

	AGE	WEIGHT (kg)	HEIGHT (cm)
	26	69	165
	30	79	175
	22	75	180
	31	88	185
	25	73	172.5
	30	77	180
	31	82	175
	29	88	187.5
	23	77	177.5
	22	82	180
	29	116	190
	22	77	182.5
	22	77	182.5
	24	77	185
	21	70	170
	22	73	175
Mean	25.8 years	80.27 kg	176.67 cm
Range	21 to 31 years	69 kg to 116 kg	165 cm to 190 cm

APPENDIX B

VOLUNTEER INFORMED CONSENT FORM

VOLUNTEER INFORMED CONSENT FORM

The purpose of this study is to determine the reliability of the Phillips biometer and technics for its use in measuring joint range of motion and flexibility in the lower extremity.

I understand that it is essential to the study that excessive lower extremity activity the day of the measurement be eliminated. Excessive activity for the purpose of this study refers to activity such as running, jogging, or bicycling long distances the day of the measurements.

I understand that three to four hours of my time will be required for this study. I also understand that once I have volunteered and have been scheduled it is essential that I meet the scheduled times. I further understand that I have the option to withdraw from the study at any time.

I volunteer to participate in this study as established by the investigator and to follow all instructions and demands to the best of my ability.

______________________	______________________________
Date	Signature of Subject

APPENDIX C

DATA COLLECTION SHEET

DATA COLLECTION SHEET

Name: ______________________________

Age: __________ Height: __________ Weight: __________

Supine

	L Test R		L Retest R	
Ext. hip rotation with hips extended				
Int. hip rotation with hips extended				
Ext. rotation leg on thigh				
Int. rotation leg on thigh				
Hamstring tightness				
Sitting				
Ext. hip rot. with hips & knees flexed				
Int. hip rot. with hips & knees flexed				
Subtalar joint inversion				
Subtalar joint eversion				

APPENDIX D

DETAILED DESCRIPTION OF THE PILOT STUDY FOR ESTABLISHING MEASUREMENT TECHNIQUES

DETAILED DESCRIPTION OF THE PILOT STUDY FOR ESTABLISHING MEASUREMENT TECHNIQUES

Development of the measurement techniques used for actual data collection consisted of analyzing each desired joint movement separately and determining movements from adjacent body segments and joints which would influence the specific motion to be measured. Once these unwanted movements were recognized, procedures were developed to control them and therefore eliminate their influence on the movement to be measured. These procedures were then conducted on several male subjects with changes occurring in technique such as different methods of body stabilization, starting positions, and instrument placement. Changes in instructional commands to the subjects also occurred during the procedure development trials.

Once the procedures were believed to be finalized, a pilot study was conducted using the same format as the actual data collection study (reliability study). The subjects, 15 males, were volunteers from courses randomly selected from all courses offered by the Department of Health and Physical Education during Summer Quarter (1977) and Fall Quarter (1977) at the University of Montana. Two subjects were scheduled each day and all measurements were taken between 12 p.m. and 4 p.m. An instruction session was held the night before the subjects were measured. Essentially the data collection study was conducted in the same manner as the pilot study concerning subject selection, instruction session and other procedural aspects such as activity restrictions. However, minor revisions in body stabilization and instructional cues to the subjects were made during the pilot study.

There were two major outcomes of the pilot study and each was believed to contribute to higher correlation coefficients in the actual data collection study. The first dealt with a change in instrumentation from the pilot study to the data collection study. A newer version of the Phillips biometer was used for the pilot study with intentions of using it for the actual data collection study. One variation in design existed between the two instruments, that being in the small aluminum cup-like devices (cupped clamps) (refer to Fig. 3e, p. 72). The instrument used in the pilot study had cupped clamps that pivoted in one plane. For example, with the entire instrument in the sagittal plane the cupped clamps would pivot in the sagittal plane. The same direction of pivot would hold true regardless of the plane the instrument was in. The cupped clamps would pivot 10 degrees in each direction. However, the instrument used in actual data collection (Fig. 1-3, p. 72) had stationary cupped clamps that did not pivot. Reliability coefficients comparing the two instruments indicated the variable the pivoting cupped clamps could have on joint motion measurements.

It is important to note that essentially the same procedures were used during both studies and that any procedure changes that did occur were minor (with the exception of hamstring tightness). The "new version" instrument correlation coefficients will be presented first with the "older version" (instrument used for actual data collection) coefficients presented in parentheses: external hip rotation with hips extended .869 (.911), internal hip rotation with hips extended .856 (.946), external rotation of leg on thigh .670 (.805), internal rotation of leg on thigh .854 (.925), hamstring tightness .933 (.988), external hip rotation with hips and knees flexed .873 (.880), internal hip rotation with hips and knees flexed .869 (.988), subtalar joint inversion .808 (.896), subtalar joint eversion .661 (.718). It was concluded, since essentially the same measurement techniques were utilized with each instrument, the pivoting cupped clamps were major contributors in the correlation coefficients discrepancies and decrease in reliability.

The second major outcome from the pilot study was a revision in the hamstring tightness movement, especially in establishing the end range of motion. Initially, in the pilot study, the subjects were asked to extend the knee as far as possible while following the same body stabilization procedures used in actual data collection. This resulted in all subjects initiating a myoclonus movement which caused the pendulum dial to oscillate freely and the investigator to estimate the proper degree reading. The oscillatory range was ten degrees for many of the subjects. Therefore, the end range of motion for the data collection study was established as immediately before the myoclonus movement started in the effort to measure the muscle tension of the hamstring group.

It is important to emphasize that the measurement techniques and instrumentation used in the reliability study resulted from many preliminary studies and an extensive pilot study to establish objective procedures. It is also important to emphasize that the investigator had to adhere to the measurement techniques developed to obtain high reliability coefficients in the reliability study.

APPENDIX E

ILLUSTRATIONS OF INSTRUMENT AND MEASUREMENT TECHNIQUES

PLATE I

INSTRUMENTATION

Fig. 1 The assembled Phillips biometer

Fig. 2 The Phillips biometer with component parts positioned differently to demonstrate the adaptability of the instrument to various size extremities. Compare to Fig. 1

Fig. 3 Individual component parts consisting of two aluminum arms (a and b) with the pendulum dial permanently attached (c), a durable plastic support arm (d), small aluminum cup-like devices which attach to the extremity (e), and the protractor (f)

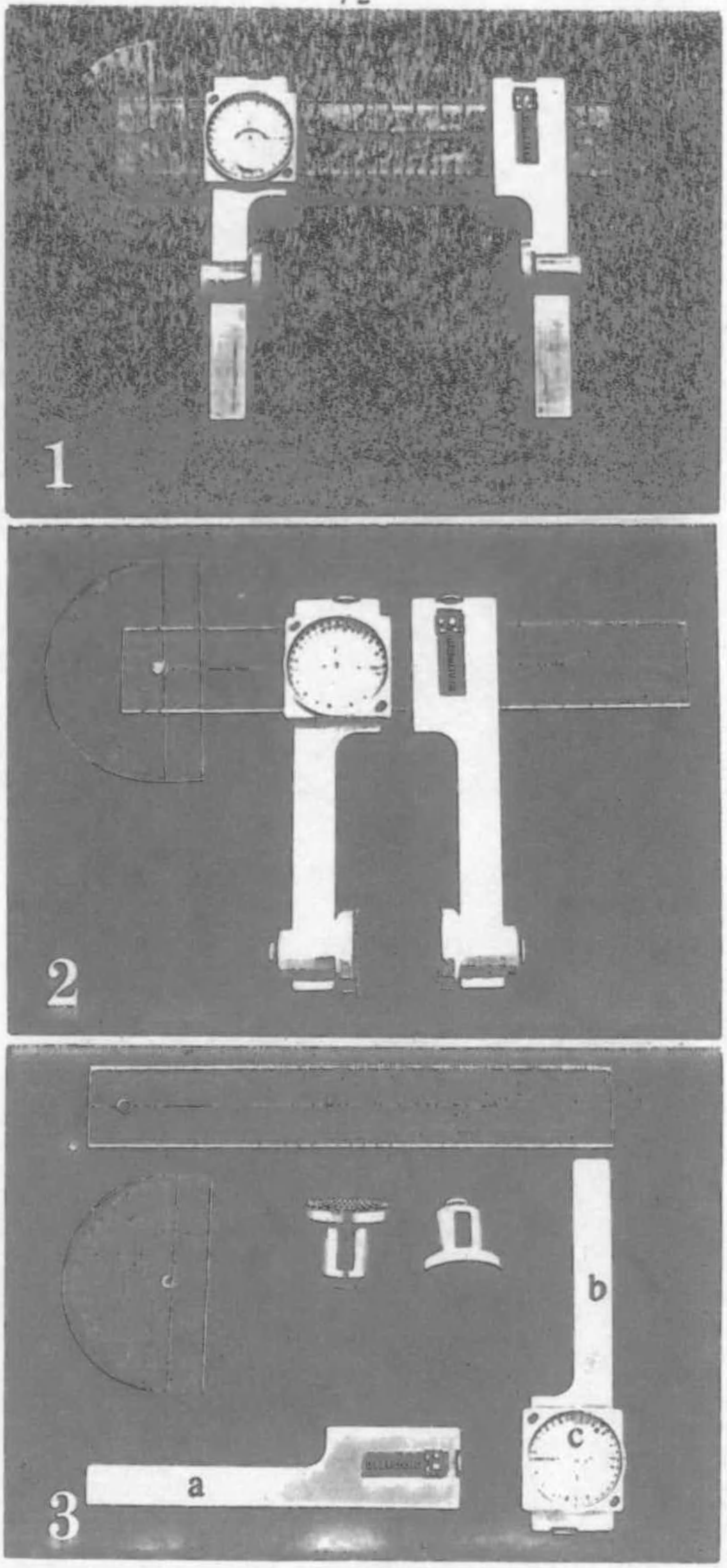
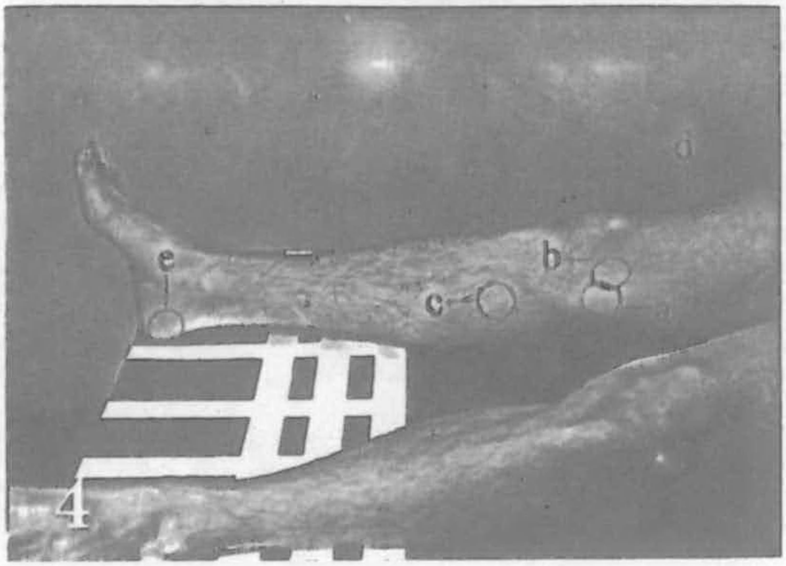

1
2
b
c
a
3

PLATE II

EXTERNAL MARKINGS AND REFERENCE LINES ON THE MEDIAL AND LATERAL ASPECT OF THE EXTREMITY

Fig. 4 External markings and reference lines on the medial aspect of the extremity for: hip rotation with the hips extended (a), hip rotation with the hips and knees flexed (b), rotation of the leg on the thigh (c and d), and subtalar joint movements (e)

Fig. 5 External markings on the lateral aspect of the extremity for: hip rotation with the hips extended (a), hip rotation with the hips and knees flexed (b), rotation of the leg on the thigh (c), hamstring tightness (d), and subtalar joint movements (e)


d
e
b
c
4

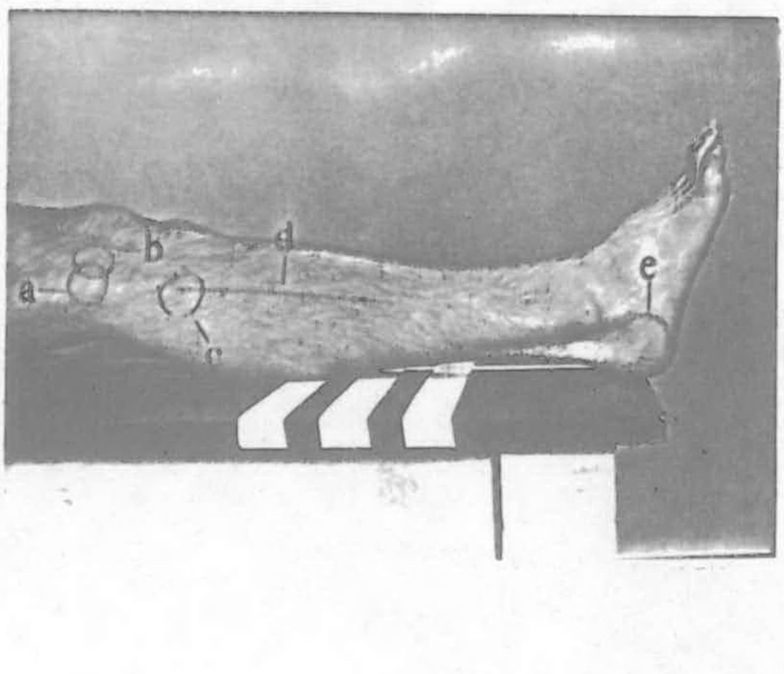

b
d
a
c
e

PLATE III

EXTERNAL AND INTERNAL HIP ROTATION WITH HIPS EXTENDED

Fig. 6 Lateral view of starting position. Cloth strap (a), instrument (b), and examiner supporting the extremity

Fig. 7 Starting position, medial view

Fig. 8 External hip rotation, end range of motion

Fig. 9 Internal hip rotation, end range of motion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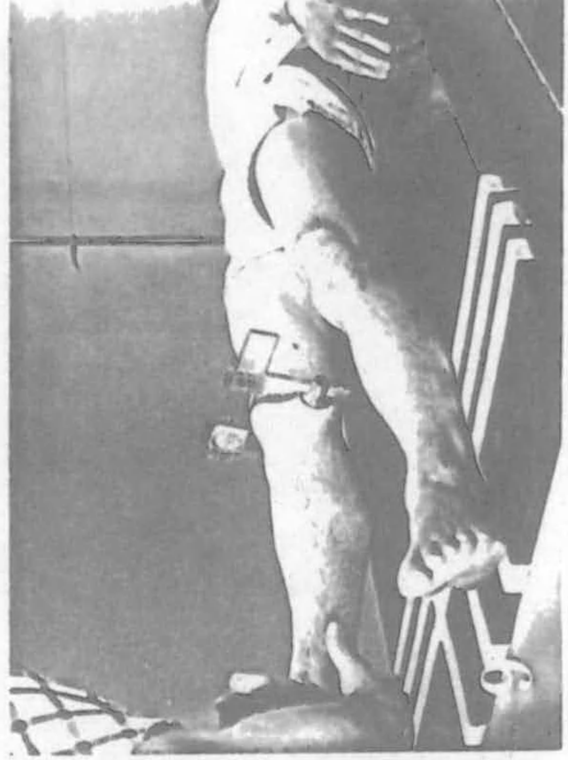


a
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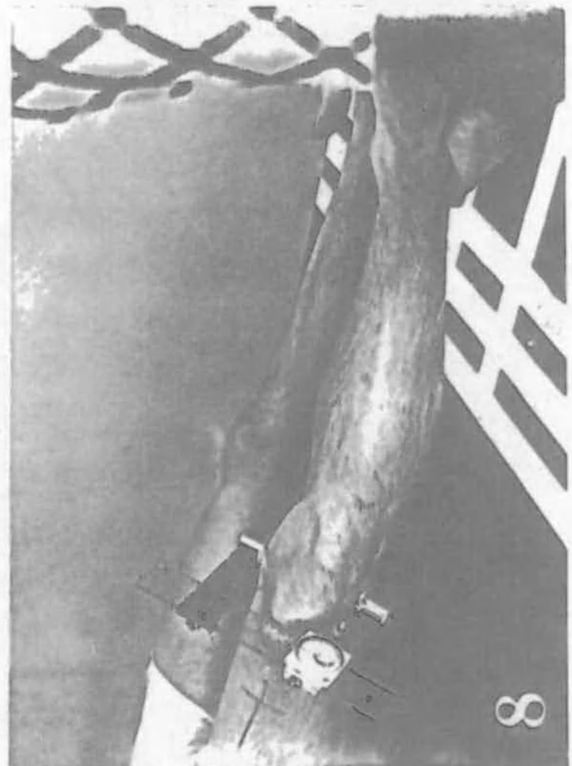
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PLATE IV

STARTING POSITION FOR EXTERNAL AND INTERNAL ROTATION OF LEG ON THIGH

Fig. 10 Lateral view of starting position with hip and knee positioned at approximately 90 degrees flexion each, and the examiner supporting the leg at the heel

Fig. 11 Subjects view of the reference lines on the anterior thigh in relation to the plumb-line (a) while the extremity is in the starting position

Fig. 12 Close-up of instrument with the extremity in the starting position

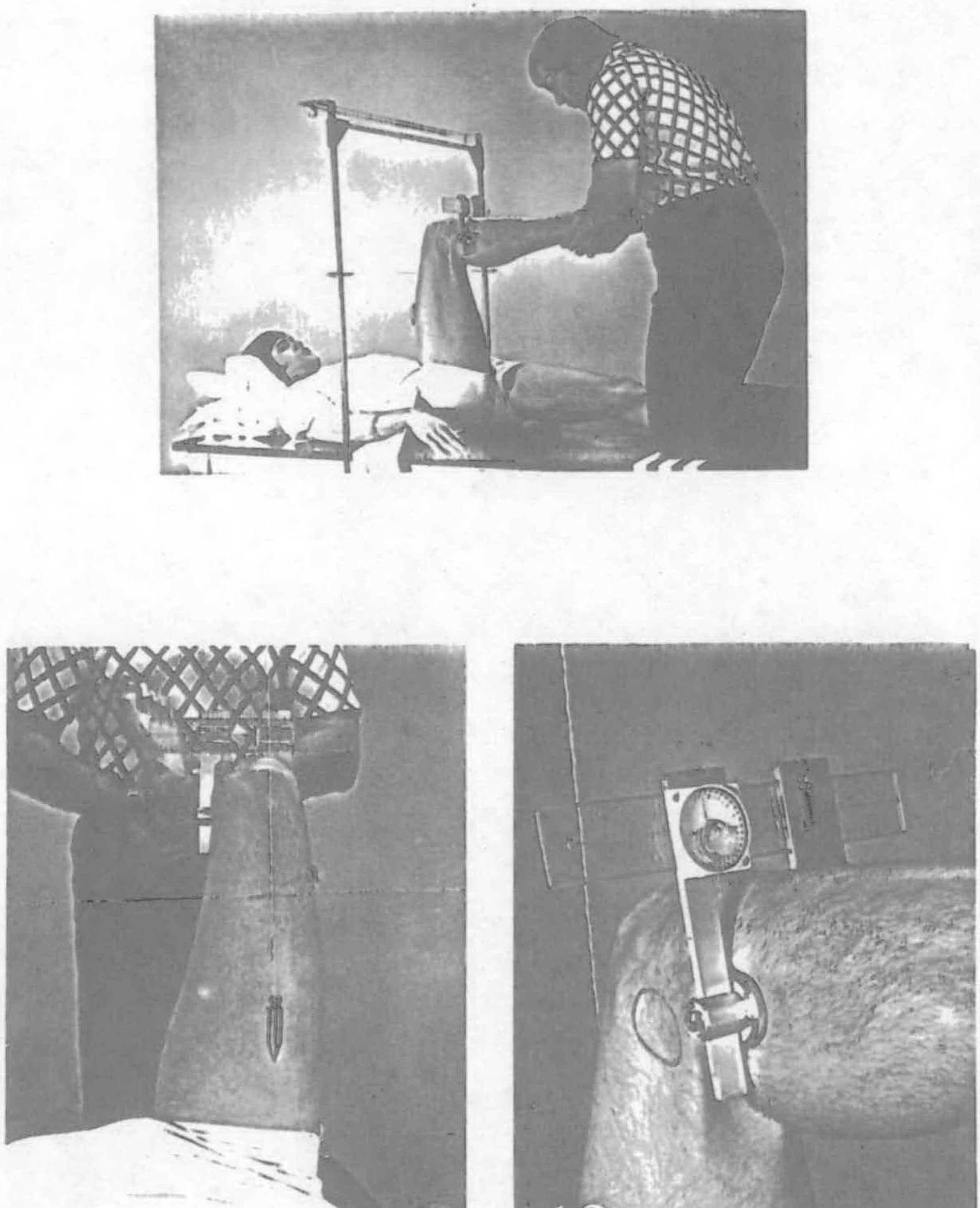
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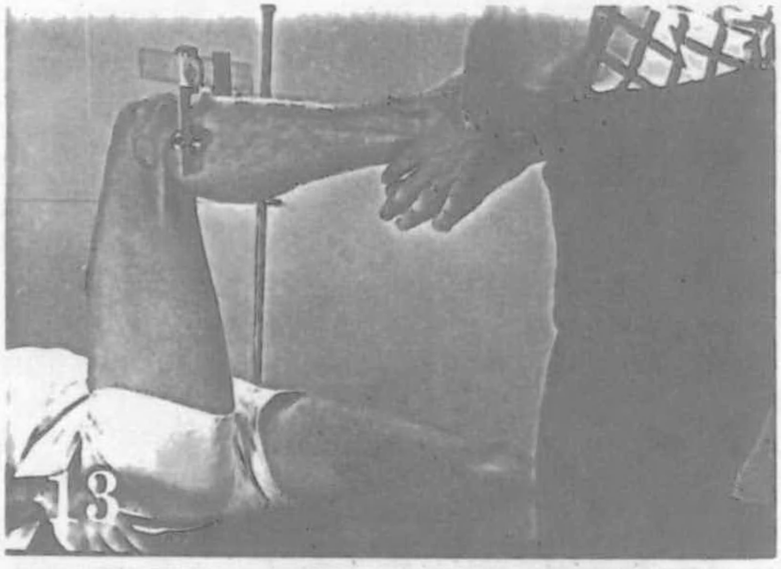
PLATE V

EXTERNAL AND INTERNAL ROTATION OF LEG ON THIGH

Fig. 13 Starting position

Fig. 14 External rotation of leg on thigh, end range of motion. Arrow notes the change of position between end of instrument and metal standard. Observe also the toes and dorsolateral aspect of the foot reflecting the external rotation movement

Fig. 15 Internal rotation of leg on thigh, end range of motion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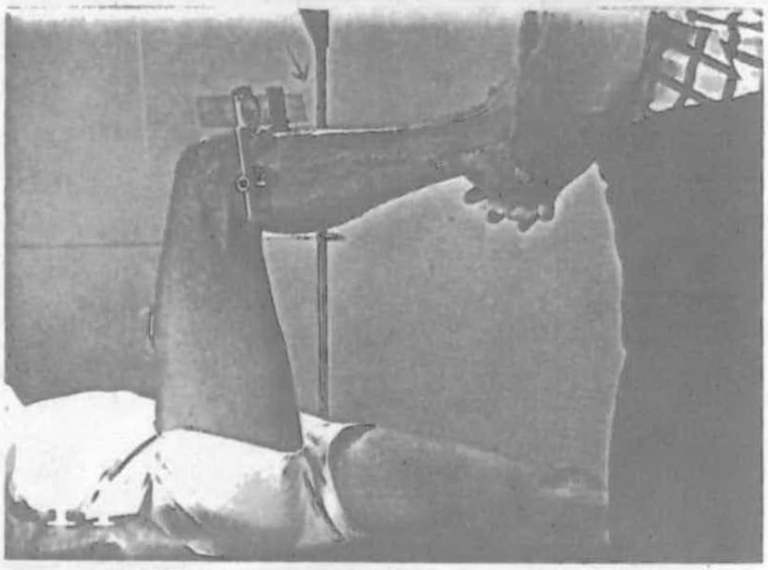
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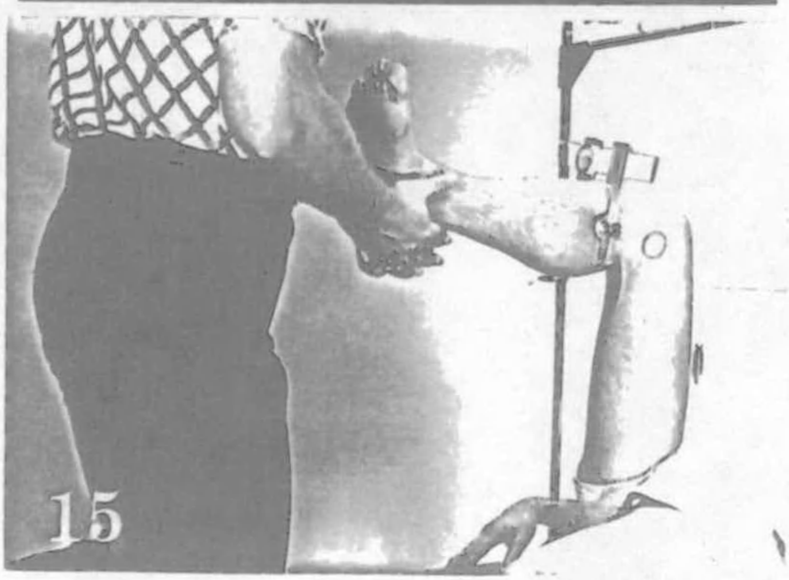
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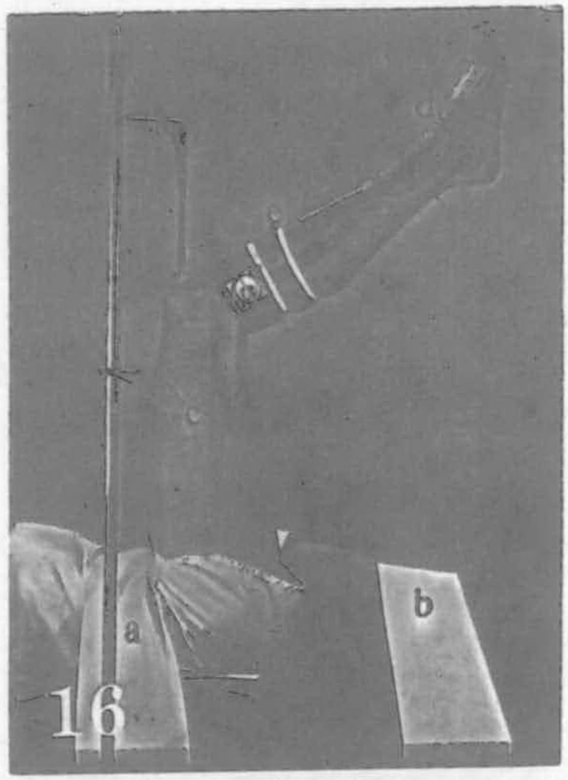
PLATE VI

HAMSTRING TIGHTNESS

Fig. 16 Lateral view, end range of motion. Note cloth straps stabilizing the pelvis (a) and the contralateral extremity (b), the anterior thigh in contact with the reference wire (c) thereby maintaining the hip joint at approximately 90 degrees, the relaxed, slightly plantar-flexed ankle (d), and the instrument positioned along the reference line (e)

Fig. 17 Close-up of the thigh in contact with the wire (a), and the instrument positioned along the reference line


a
b
16

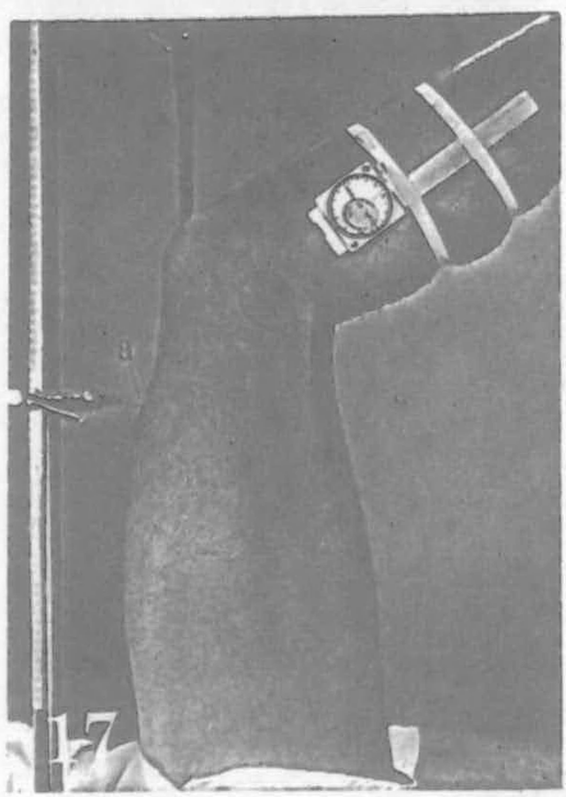

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PLATE VII

EXTERNAL AND INTERNAL HIP ROTATION

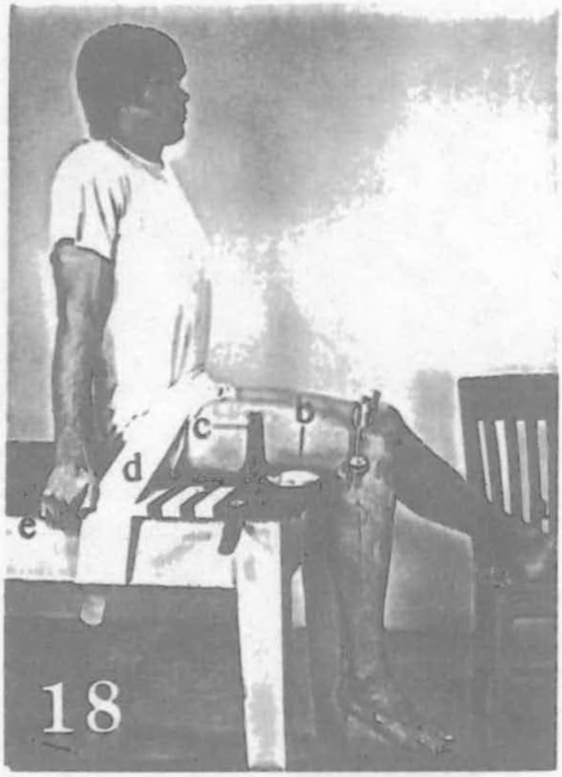
WITH THE HIPS AND KNEES FLEXED

Fig. 18 Position of subject and stabilization procedures including contralateral extremity placed on a chair (a), sandbag at distal end of femur (b), metal bracket to keep thigh in proper alignment (c), cloth strap for control of pelvic elevation (d), and subject grasping table top and pulling upward (e)

Fig. 19 Starting position established by the extremity assuming the normal amount of external or internal hip rotation in the relaxed sitting position

Fig. 20 External rotation, end range of motion

Fig. 21 Internal rotation, end range of motion


c
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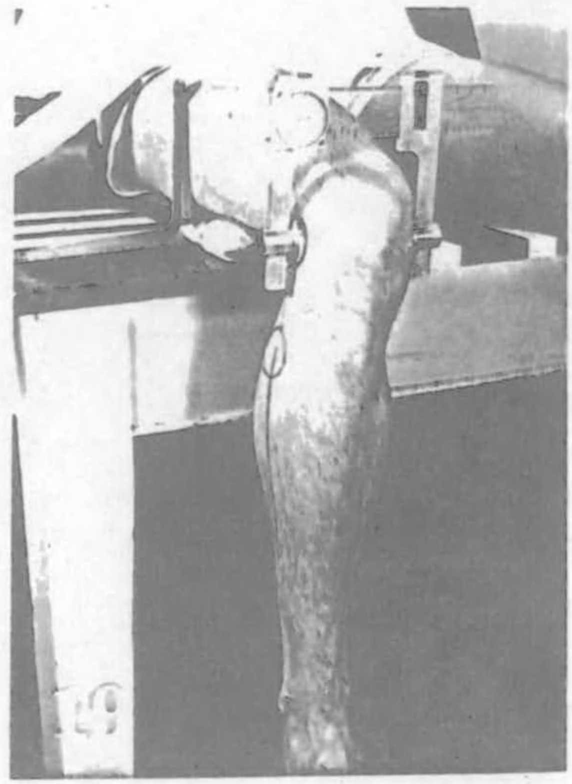


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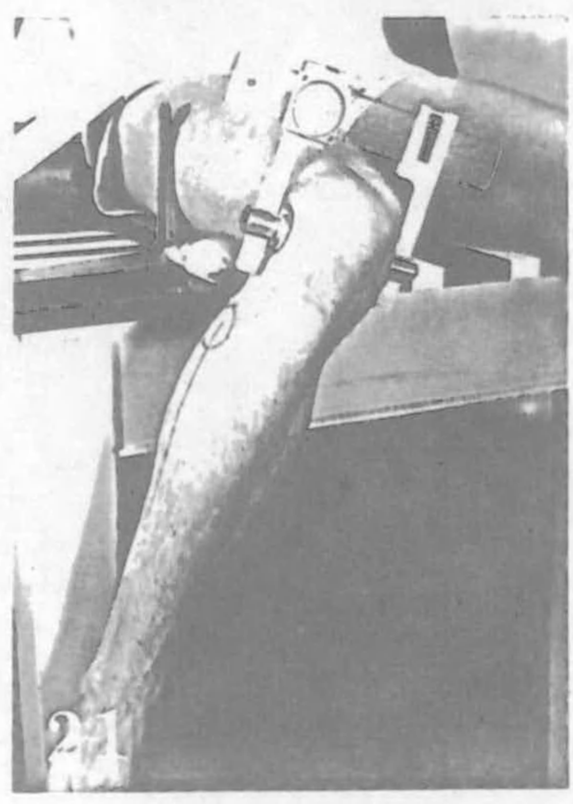


PLATE VIII

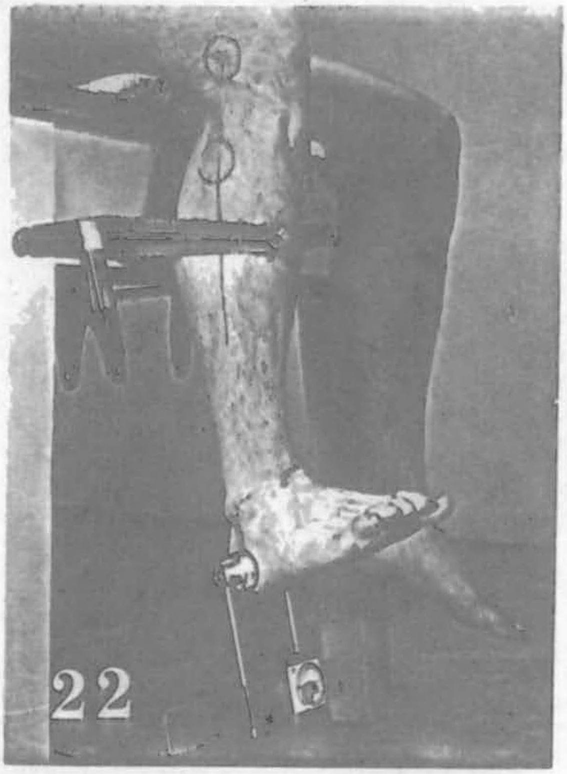
SUBTALAR JOINT INVERSION AND EVERSION

Fig. 22 Position of leg in starting position including metal brackets to secure the leg in the sagittal plane (a), foot dorsiflexed and instrument in position

Fig. 23 Starting position, degree indicator at zero degrees

Fig. 24 Inversion, end range of motion

Fig. 25 Eversion, end range of motion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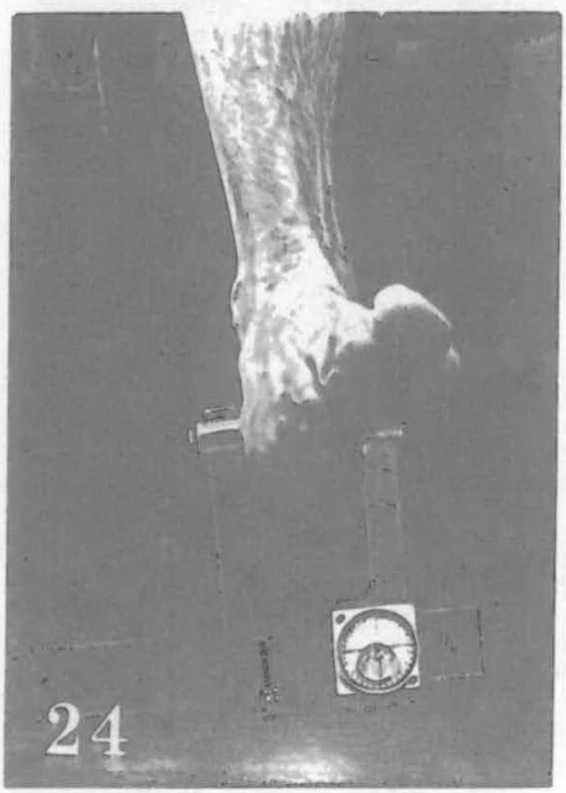
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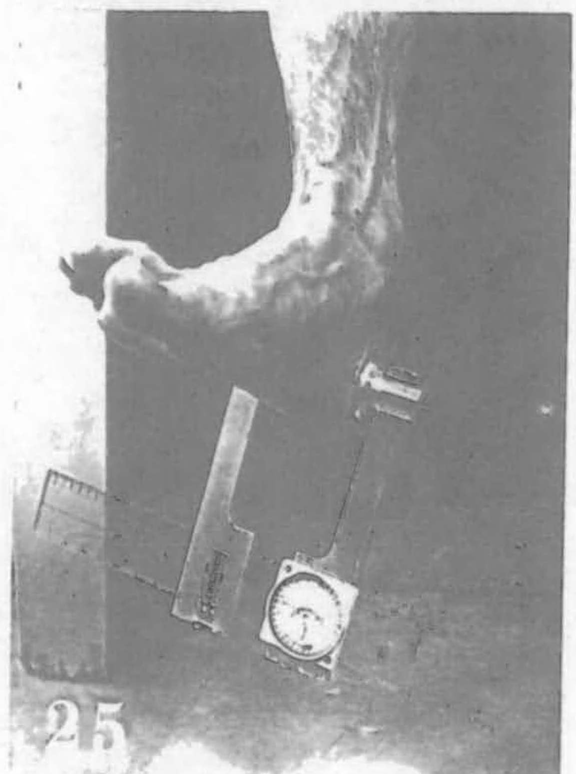
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